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ADVANCED CONCEPTS FOR COR (CONTINENTAL OPERATIONS RANGE).(U)
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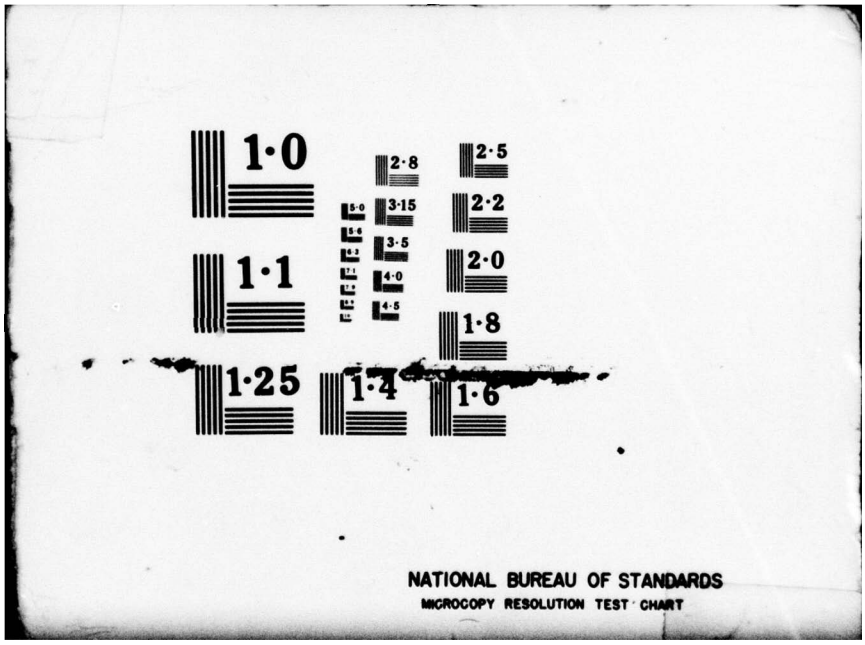
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MICROCOPY RESOLUTION TEST CHART

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PROJECT MANAGEMENT
DEVELOPMENT
MEASUREMENTS
INSTRUMENTATION
SYSTEMS
TRACKING
TARGETS
TEST
OPTICS - LASER
TELEMETRY
EVALUATION
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TECHNICAL MEMORANDUM NUMBER 103

ADVANCED CONCEPTS FOR COR [redacted]

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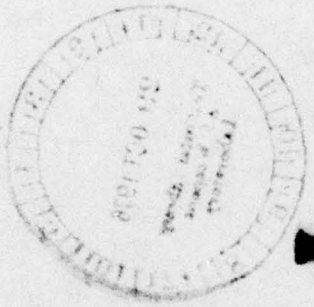
TECHNICAL MEMORANDUM NUMBER 103

ADVANCED CONCEPTS FOR COR



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19 April 1974

Prepared by

Eugene J. Pollock

Test and Evaluation Systems Program Office
Air Force Special Weapons Center

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(6) ADVANCED CONCEPTS FOR COR (CONTINENTAL OPERATIONS RANGE)

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A. INTRODUCTION:

This report is primarily concerned with advanced concepts for COR. Now the guiding documentation, Development Concept Paper 111, talked about a number of major items. The one most relevant to this discussion is the fact that we will be concerned with very large scale exercises. Although it did not really give numbers, we have since received documentation from TAC which talks about 300, and that is the number we have used in our development. It also defines very large areas of concern, mainly in the long haul, the triangle between Nellis AFB in Las Vegas, Hill/Wendover/Dugway near Salt Lake and the Fallon area out near Reno. This is quite large, a couple of hundred miles on each side of the triangle, so we are, in fact, concerned with quite a large area. In addition, it talked about specific terminal areas. That is, we would do different kinds of things, maybe an ECM area here, an air-to-air combat area elsewhere, eventually tieing all of the three points that we mentioned before into one system. It talked about many different kinds of targets and a few that we are concerned with are listed on the slide. Certainly, we are going to have fighters, cargo airplanes, choppers, and by the way, one that worries us a little are, these so called, flying ranchers which have been flying through that area and will continue to fly almost at will. We are sure some control will be exercised on them, but we have that

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D. OBJECTIVES (BLUE):

Now the objectives of the Blue Force or OT&E as I said, Operational Test & Evaluation. And this list of objectives by the way is right out of the definition manual in the Air Force, so one can't argue too much, at least conceptually, with it. The operational performance requirements we are going to almost skip over and the suitability for service use probably doesn't even need a COR, but the last three are tremendously dependent on a COR. For tactics and doctrine development, certainly the Commander must know that his tactics are suitable to get the weapons and the ordnance into the appropriate places. We want to make sure that continued operational needs are met. The threat is going to change. We know we will have new threats as time goes along, and must make sure that the systems we have on hand can meet and live in these new threats

E. OBJECTIVES (RED):

Now the Red objectives are almost the opposite. We have to maintain a current threat. We can't over-emphasize that; however, we never do this very adequately because of the money constraint so we do generally the best we can. It always acts as a counterforce to the Blue Force and really is the exercising system against which the Blue Force has to work. We have listed five major things that the Red Force is concerned with, certainly their COM CONTROL C^3 SYSTEMS, the SAMS/ ANTIAIRCRAFT FACILITIES. There are aircraft in the Red Force of course, and there are ground forces in the Red Force. We will have to set up targets that are realistic but will in fact exercise our system to find out how well they operate.

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F. OBJECTIVES (WHITE):

Now, the one we are going to talk about most is the White Force. The need for the White Force is manifold. We are going to talk about what we think are the six most important factors to accommodate the Red and the Blue Forces in every way possible, provide the controlled air and ground space, in fact, do the housekeeping, if you will, for both of the forces. The next factor though is the beginning of the big technical difference from existing ranges. The White Force must score both the Red and the Blue Forces; this in itself is not a minor or easy task. It must monitor and control all COR traffic, and I underline the "all" because unlike some other ranges, we don't have restricted air space. We have to live with other kinds of traffic; it won't be a closed range, it will be a scheduled range, if you will, and we have to know where any and all traffic is, that might be on the COR when we are in fact exercising. We certainly have to exercise range safety and I think you know that in itself is one of the toughest jobs because we are talking about large numbers of aircraft on some occasions and trying to make sure that they are operated safely. Safety is a major consideration in itself. This also includes making sure that weapons don't leave the range, etc. And the last factor is probably going to be the most difficult to achieve, but we think probably it is as important as any other one and that is to insure the integrity of both the Red and the Blue Forces. You do not want the White Forces to cause them to modify their tactics to fit the White Force situation. You want them to go out and do the job as

they see fit within the constraints of safety and reasonableness. Other than that, they should have a free hand.

G. WHITE FORCE:

Now we kind of put these things together in the orderly matrix to see what is the commonality of them, and we think you can see the surveillance and control, the scoring, the range safety. When you list them, you come up with almost the same requirements, needs if you will, across the matrix until you get down to the second or last line on the results and herein is the big difference. In the Red and the Blue scoring, one wants to know what the actual results are as they happen, and we emphasize results. However, in the range safety considerations, we are always working with statistics, the probable effects of projected air operations and what will be the future impact. Time, position, identification and communications which are absolutely manadatory for any range, and it is something we are going to be spending the rest of the time talking about.

H. WHY DO WE NEED:

First of all, let us raise a question that seems very obvious to us but it is one that we seem to get into quite a bit of discussion on. Why do we need time and position? We talk about TSPI as something we all need but now let us see if we can break down why we need it. Well, you need time and position primarily to tell where the target is now, and to tell where the target is going to be in the future. We don't have to go much farther than just say in the range safety consideration you want to know from the trajectory that is at hand what is going to happen in the future and, of course, the same thing

is needed in other things where TSPI is being used. A sequency of positions which is what conventional ranges use today; in fact, almost every one of our systems today uses sequence of time/positions to estimate velocity and acceleration. We are going to propose a different approach in this particular area. The point to be made here, is that if you use position and time to come up with the derivatives, we know these time position measurements are noisy and of a direct consequence require very high data rates, long data streams in order to get the derivatives. There is a much better way where we drastically reduce the data rate from a high of 30 times a second down to some numbers around 1 sample per three seconds. We are talking about 100 times less.

I. TIME:

The first thing we had on the White Force matrix was time so we will spend a little while discussing time. Time accuracy is important and we will discuss it, but it is not the message to get across here. Our concern is with time tagging. One millisecond accuracy in time is rather easy to achieve. It is necessary to point out that a number of things influence time accuracy and, in general, you are talking about tens of microseconds in order to get the millisecond accuracy; the RMS of all timing error considerations is going to require it. In COR we are very fortunate in that LORAN-D runs through the COR area itself so that there is no need for central time. What we are proposing here is that each instrument have its own autonomous clock. This includes a LORAN-D receiver, a cesium standard and a time code generator, as

the three necessary ingredients of the timing system. Again, the item of greatest concern is time tagging. We time tag the data by entering time into COR in a local on-site computer at the same time we take and enter metric measurements. This is the only way we have been able to get time tagging accurately combined with the metric data and we might point out that time tagging, in the past, has been the biggest source of error when we evaluated existing ranges, and in fact, we have looked at them all. We propose to send 27 bits time of day and nine bits day of year. The nine bits, of course, is slightly larger than 365 days. The 27 bits divides 24 hours into milliseconds so that we have a good handle on the time resolution.

J. TIME-SPACE-POSITION-IDENTITY (TSPI):

Let us talk about TSPI again. TSPI is concerned with time space position, i.e., the trajectory of the target. What is its velocity and its acceleration? It is only when time and position is added to these derivatives that we can predict where the target will be. Even a cursory look indicates that this must be available in real time for traffic control, scoring and range safety. Identification, we think needs no further explanation.

K. INSTRUMENTATION PERFORMANCE:

This TSPI will be made available to every instrument. We are proposing to send this TSPI into each instrument and to use it to evaluate how well the instrument is performing. For instance, in the case of a search radar, we intend to produce gates under each target based on TSPI and to measure the J/S ratio, which will be discussed

in a moment. In the past 20-25 years there has been sort of a continuing argument about whether we should jam search radar. Many people suggest that that is not good, but we continue to do it because we never really measure the penalty associated with jamming. In this proposal, we are certainly talking about doing evaluation of both the benefits as well as the penalty of countermeasures. All too often we have found in the past that a weapon control radar that is being effectively jammed continues to exercise its function repeatedly against the same nonprotected target. In realistic life, he might have shot him down and with that target out of the way, would go to another one. Removal becomes an automatic process. The fact that he can shoot the same one down 10 or 15 times has very little bearing on the problem.

L. ON TIME DATA:

Still on the subject of TSPI, and here is where we are beginning to tell the big difference in the way it is done today. It must always be predictive and in real time. Again, we are interested in where that target is going to be. We are not interested in where it was. We will display in central control or any other place that TSPI data at the current epoch. The TSPI data on the bus that we are going to describe may be seconds old. What we want to do is tell you where that target is now by moving it up to the current epoch. What you will observe on the display is where the target is at the current time. By doing this prediction, we can begin to lower the data rates. You see we are going to be sending the derivatives in the data stream and

as we said before, instead of having to figure out what the derivatives are after we are through, we will have them in real time. We have done this on other ranges, like the Eastern Test Range, which greatly reduces the data rate in the data stream one needs. TSPI will be common for the whole range. Now what is meant by this? We don't feel that one can live with different instruments putting out different TSPI data. You can't separate targets and you don't know which one you've got. In the system we are describing, there will be one TSPI common answer out of all instruments on the range. Until that has been achieved, we will continue to adjust them until they do.

M. UNIVERSAL COORDINATE SYSTEM:

We have talked about time and derivatives. We would like to talk now about a coordinate system. First of all, we feel it is absolutely necessary in a range of this size or in fact desirable on any other range, that is in a real-time mode, to use a geocentric coordinate system. We are proposing using EFG coordinate system. E is the plane of prime meridian, F is the plane of the equator, and G is the plane of the axis of rotation of the earth. We will send in the EFT data stream for each component, position in 30 bits, velocity 16 bits, acceleration 7 bits, all at a common epoch (time). Now, although a series of advantages accrue from using the geocentric coordinate system, one of them is not displaying information. If displayed in the geocentric coordinates, you would not understand it, we would not, none of us would. However, we are used to looking at things in a map mode; so we will display things as XYZ over a map so that you can then locate your target with reference to the earth surface. On the other hand,

if we send data into instrumentation, radars, or airplanes, XYZ does not do a bit of good. That man in the aircraft lives in a world of range, azimuth and elevation, and that is the coordinate system that we use when presenting data there. Regardless of the data coordinate system displayed, it will all be referenced to a geocentric coordinate system. Now the biggest advantage, and there are a number of them, is that we do not have to locate any of the sensors that are producing the data in the data stream. The data is all referred to the center of the earth so in the data stream, one only have to carry the targets, and not the location of the collection instrument. We think you can see that if we had 15 targets and 15 sensors, we are reducing the amount of data carried by orders not just twice.

N. EFG COORDINATE SYSTEM:

The EFG coordinate system shows three orthogonal planes intersecting at the center of the earth. These planes can define the location of a target at any point in the space involved. We have used it out to lunar distances and certainly we are not going to fly airplanes out that far for a while, but nonetheless, we will use the same coordinate system. The Eastern Test Range is, in fact, tracking space objects in the same coordinate system as the COR cracking airplanes. It makes no sense to use multiple coordinate systems, so we will talk a little about contaminent. The use of multiple coordinate systems is one of the biggest sources of problems when we move into combat areas like Vietnam. We all tend to use our own local coordinate system, and it is, therefore, impossible to tie everything together. You will find that

when using a geocentric approach, regardless of where in the world we go, we will have a common system to refer to. The hatched area shown on the geocentric slide represents what we normally do now, which is the use of a localized plane. We locate ourselves in XYZ on the surface of the area.

O. XYZ COORDINATE SYSTEM:

Now XYZ, or east, north and up, to be more explicite, is a rectilinear coordinate system located on that hatched area. The earth is not flat, but we treat it as though it were, which in itself, accounts for quite a number of errors. One can take into account the curvature, but we frequently don't even do that. The XYZ coordinate system is good for display purposes, and that is primarily what we are going to use it for. Although we will do some computation in this coordinate system, we generally find it more convenient to use the geocentric coordinates.

P. RANGE, AZIMUTH, ELEVATION COORDINATE SYSTEM:

To make sure we understand what we meant by range-azimuth-elevation, those of you used to flying airplanes know that your radar and you flying inside of it, simply locate the target at a range, at an azimuth from your center line, and at an elevation above or below your center line. We find it difficult to draw a common chart that will show them in one. This slide shows two aircraft, but they are the same airplane. It is showing what is seen from the inside of instrumentation or airplanes. We almost never do computation in RAE because it is nonlinear; rather, we transform to/thru it for display.

Q. STANDARD REFERENCE:

We have talked about basically two things. We have talked about the time coordination of the metrics, and we have talked about the uses of a geocentric coordinate system to tie them together. The third

thing we want to talk about is the standard reference. In the past, we leveled our various radars and instruments to each local vertical and tried to tie them all together. If one looks at the local vertical change over relatively close locations, you will find that we all are trying to correlate or to locate against some nonstandard reference. We have been extremely successful when we turn to the stellar calibration mode and tie our systems to the stars. We want to point out that this need not be done very often; in general, it is done once for each location and we then simply use a local vertical determining device, a level if you will. In the old days we used all sorts of spirit bubble instruments; today we are a little more sophisticated, using electronic bubbles, if you will. There are two main candidates here, one is a Talyval level built in England, and the other is the Minuteman level which is coming into much more frequent use. What we are really trying to say here, is if any site can randomly point to 40 stars in the hemisphere, and there is another set of instrumentation that can point to 40 stars at some remote location, gentlemen, we will assure you on static targets you can pass data back and forth between them with the absolute certainty that they will both see the same target in the crosshair. Once you achieve this, we think you can begin to see we have got a real network. We are going to produce the same kinds of answers. Again, we will map the stars into our electronics so that we don't need to look at the stars everytime. There are clouds sometimes, for instance. We map the star deviations and add the deviations to the local vertical measurement so that we always have a constant reference. We can also locate each of our instruments by the stars. A first order

survey is not always as good as it ought to be. We learned a long time ago if we don't get the right answers on the stars, first check time, and then check geodetics. We have never found a time when one of those two didn't solve the problem. In COR, we plan to evaluate all the data via TSPI bus on a periodic basis. What we are saying here, and we will talk again about this a little later, is that we will use an airplane and every instrument will track it (the aircraft), putting their data on the bus, and they all better be the same. We will correlate them, and if we find one deviating, we will fix it. We don't take it out of data as a bias.

R. PREDICTIVE POINTING:

As long as the target is relatively nondynamic, stars for instance, there is no problem. Time tag correctly, use the geocentric coordinate system, and use the stellar reference system; gentlemen, they are all tied together. There is no question they will pass data between each other on an absolute basis. However, airplanes on COR or targets on a missile range are hardly static, and we find we must solve two more problems, but only two. It is not complicated, and once you have solved these two problems, you have solved the total TSPI problem. The first problem is something called dynamic lag, and the second one is the simultaneous requirement, a diochotomy if you will, between wide and narrow bandwidths. We will hopefully make both of these clear in the next three slides.

S. DYNAMIC LAG:

The sensors that we use, radar, laser, etc., can only measure position. It does not matter whether it is an ACMR trilateration

scheme or whether it is an IFF or a telescope. It can only measure position, or in many cases, not even total position, but rather components thereof. There are other devices, accelerometers that can measure changes in velocity but even these must be initialized by position. However, we want to exclude these from the current discussion. None of them can measure velocity, you either integrate from acceleration to velocity or differentiate position to it. What we need to do is to maintain time, position, velocity and acceleration trajectory. By only measuring position, we would have to measure a lot of positions before the trajectory could be obtained. We know the target is accelerating, there are not many cases in the natural world where a target is not accelerating in the frame of the sensor collecting the data. In fact, if you really analyze it, the higher derivatives all exist. In this discussion, we are going to stop with acceleration. You will always lag/lead because you have no way of telling what that acceleration or deceleration is until it has happened, and that constitutes dynamic lag. It puts very large errors in your data; and, gentlemen, you can almost never take them out once they get in. We have documented many cases where, in post flight we made the data worse, not better. The solution is to simply predict where the target will be, using this trajectory, and then use the position measurement to evaluate how well we do on that trajectory. We will adjust that trajectory until the position variance is zero. At that time, there will be no dynamic lag in the data and we will be staying on the target and not following it, in a conventional sense.

T. <u>CONVENTIONAL VS SEPARATE POINTING/TRACKING</u>:

In order to do this, however, we must have smooth data. If the data

is rough, the time to estimate the trajectory becomes longer and longer, and with very noisy data the time required becomes almost infinitive. A conventional tracker such as a microwave radar system, a telescope, or what have you, all have error detectors. The error signal will be sent as data into a servo system which will move the mount. The idea is, the error signal will drive the mount so they will be in the center of the beam. This is never achievable for a number of reasons, the biggest reason being that the menseration data is very noisy. If noisy data is introduced into the servo system, and the servo system must have gain, then amplifying the noise will be amplified to such an extent that the mount will move very eratically across the target. A video tape will be shown you right after the briefing, which will certainly demonstrate this. Everything would not be lost even with relatively rough data if we stopped there, but the data must be sent out of the radar or airplane to somewhere else. For example, take a radar and send the data to a plotting board somewhere else, or point a telescope onto the target. We now need a set of encoders, resolvers, or equivalent, so that the radar data is available to the outside world. What invariably happens, is that the data sent to the outside world is pretty bad, so we build all sorts of computer systems called data correctors, to hopefully correct the data. As we said before, although it does improve the data, there are quite a few documented cases where this post flight data processing makes the data worse. In most current instrumentation, we now have an encoder and a computer system installed. This computer, in many cases, is not on site but some big

central computer. What the computer is trying to do is to message all the data to make it fit and agree with other radars, etc., an almost impossible task. Consider for a moment that this nonsmooth data almost never allows one to remove even the dynamic lag that we have been talking about, so we developed something called on-axis. On-axis is different only in the use of the equipment. No new equipment is added to the system. We will use the same mount. We will use the same sensor, in this case microwave, the same servo, the same encoder, and the same computer, but let us split the system down the middle--one part is tracking and the other pointing. Gentlemen, let me make one more observation. In every modern radar you will find a Type 2 servo on it, but nobody uses it because the Type 2 servo blows up in the presence of noise. A Type 2 servo is a servo that has velocity memory. If you feed it noisy data, it will go ape. So you go back to the position loop (Type 1) that will tolerate the noisy data, it is that simple. You will remember, we said we could get rid of the dynamic lag, but first we need to get rid of the noise. The way we are going to do it is to use that state vector, the time, position, velocity, acceleration. We will integrate the vector forward in time at least a hundred times a second so that we get very wide noise free bandwidths.

We can now use the Type 2 servo system. Through the use of slew checks we will determine the constant of acceleration (Ka) for the mount/servo system. This is automatically done in the computer. Now $Ka = \frac{\text{acceleration}}{\text{error}}$. Since we are using a state vector (TPVA) to drive the mount, we know what the acceleration is. Also, the error will be the maximum value that will be tolerated, i.e., the least bit of our

encoder. We will solve for that term to be added to the drive data to reduce the error below the least bit of the encoder. When this data is added to the drive data, then dynamic lag is removed before it ever gets into the data. We must emphasize that this process works only in the presence of noise free data. To this noise free data we add corrections for droop, mislevel nonorthogonality, refraction, skews to each term and move the mount so that, in fact, we follow the target. The error correction terms were determined by celestial calibration. Now since we are doing this with a state vector in a computer, it is for all practical purposes noise free. If we can keep that state vector correct, then the target will always be dead on the crosshairs, i.e., on-axis. There is no physical reason why that is not so. If we can keep the crosshairs on the target all of the time and do it smoothly, then we will have solved the problem, the ditchomy of accuracy and smoothness. Notice, we have not said a thing about processing that noisy microwave data. We now process that noisy data through a narrow band filter. Now don't forget our state vector is old. It is quite old. We are integrating it forward to a new time but we still have that same state vector we started with. Since the microwave data is noisy, we will run it through a filter which we refer to as an Alfa Beta Gamma filter, or a fading memory Kalman filter. This Alfa Beta Gamma filter adjusts position, velocity and acceleration. Alfa adjusts position, Beta adjusts velocity, and Gamma adjusts acceleration. Now if we adjust the state vector slow enough, we don't disturb it. We will not disturb its smoothness as it is integrated forward and at the same time make it accurate. That is exactly what we do. We have one

other thing we want to describe called the bandwidth control. We are continually solving for delta position, velocity, and acceleration to be added to the state vector with the filter all the time. But, we do something else. We will strive to keep our error detector data random. If we can, then we have extracted all of the available information. Let us say, for a moment we have 160 PRF which happens to be an IRIG standard. We are going to take 16 of the 160 pulses and we are going to add them. Since the data are noisy, they are going to be jumping up and down, and we will attempt to get the zero value. Let us say we get values with something like plus 4. We add up the sequence of the next 16 pulses and we come out with plus 7. Now the fact that on two sequential 16 pulses, we got plus says the data is trended, we are above the boresight. And if we had gotten both below, we would have been still trended but in the opposite direction. But suppose of these, the first one was plus and the second one was minus, what would that indicate? That would indicate that the data are random about the boresight. Now that is the important consideration here. We want to make sure it remains random. If we can point that system so that it remains random, we are on that target with absolute certainty. That is exactly what we do. If we take two sequences of 16 pulses and multiply them together and we get a minus, then the data are random. The bandwidth goes toward zero and we do not apply corrections to the state vector. It is correct. Now, using the process, adjust three components, up and down, left and right and in and out, independently. You should see that one component can be trended and one can be right. When all stay random, no adjustments are made. We are driving on a state vector,

and the target is going to stay in the crosshairs as long as the vector does not change. The minute that the target airplane turns, or does anything else, the change is sensed in the first 16 pulses. We are really using 10 noise free samples a second. That is a lot of data. Ten noise free samples is far more than we need to get first and second differences for acceleration and velocity. Straight forward simple, but do not try to take shortcuts. We tried most of them. You might have a good one but let us talk before you do. We have seen too many millions of dollars dumped away because somebody did not understand the process. Let us go back to the chart. Notice that there is a half of the on-axis system called pointing. We build only this half of the system when we point instrumentation remotely. This is the concept used in the on-axis telescope which will be discussed later.

- - NAVSAT

We have looked at some other systems that give time, position, velocity, and acceleration. One of them is NAVSAT. NAVSAT advertises ten ft cube accuracy, and in real time. It is going to be beautiful if it does. It looks very good. We are talking about the same accuracy as the on-axis systems. However, for the White Force to know the aircraft location the data will have to be telemetered down. That is a serious constraint. Although there is no inhabition to put in a telemetry system, we would like to avoid it. We may end up with such a system on a world-wide basis. What was DNSS now is the Earth Locating System. Although this requires an aircraft modification, it falls into the same category as IFF, in that the whole fleet will probably be modified for other reasons than COR.

- - SEEK BUS

Now SEEK BUS is another one we have looked at. It is a digital data link, it is not a positioning device at all. It requires a modification of the vehicle, and is only installed only in the F-106. If we do need to transmit status back to the ground, this is possibly the best way of doing it. In the system we are talking about, we don't see too much need for that. If we need it, we think we have a prime candidate but again it means modifying every airplane and we sort of rejected it on that basis.

- - TSPI Candidate Systems

We have mentioned several systems which are candidate systems such as the ACMR, and the RMS 2. We should now like to take a quick look at several of the systems that hold promise for selection on COR. These are in no particular order and there may be others still to be evaluated so there is no significance to their listing. The first is the ACMR which is a multilateration system requiring as a minimum the installation of a pod on the aircraft. This pod along with other equipment contains the ACMR aircraft beacon. There are several deficiencies associated with this instrumentation. It is difficult to see how the ACMR can be used on a large scale exercise when one considers the number of pods required and the fact that many aircraft cannot carry pods at all. Of great concern are the shadowing and area limitations. Another major concern is the inherent deficiency in the Z axis of many planer multilateration or multiangulation systems. A third concern is the inability to use this system for other than simulation purposes as it

seems to have no live weapon capability. The ACMR is a very strong training system for air-to-air guided missile setups and this was the primary purpose for which it was designed. A second system is the RMS 2. The RMS-2 is again a multilateration scheme. Associated with this multilateration is the same inherent Z axis weaknesses. It has been proposed that this inherent weakness could be overcome by using an airplane in orbit to give Z axis strength. However, it will take a great deal of external survey to remove the uncertainty in the aircraft position. It does appear to be a prime candidate for ground vehicle tracking where Z definition is not important. It is difficult to see how the RMS 2 can be used on a large scale exercise when one considers the number of pods required and the fact that many aircraft cannot carry pods at all.

A third candidate is conventional radar. These systems are commonly known as the error tracking radar, since this system must see an error to track. They do have a very serious deficiency in that the system always either lends or lags the target, and this error is almost impossible to remove. In addition, the conventional radar tends to lose track under adverse conditions.

The fourth candidate is the ON-AXIS radar or as it is frequently referred to, the predictive pointing system. The ON-AXIS system overcomes the deficiencies in conventional radar primarily in that it is always directly on target. The ON-AXIS system is a skin tracking radar and will impose no modification whatsoever to any aircraft that will be used with it.

The fifth candidate is IFF/SIF. IFF systems are installed on all DOD combat aircraft. A feature of this system is that all aircraft so equipped will always be seen by the ground system and those equipped with the SIF feature will give positive identification. This is all done without additional modification to existing aircraft and is the only system studied which has this feature. It does not however, produce position data as a normal feature but rather gives only two coordinates of position, azimuth and range. Some aircraft have been modified to send barometric pressure altitude to the ground and this when transferred will result in strengthening of the position capability of the SIF. There is no feature in any of the current IFF systems to give trajectory data, unless tied into BUIC or SAGE.

The sixth candidate is the NAVSAT, which was described before. It is a multilateration system but of great strength in all coordinates because it is nonplanor. It does require beacon or installation in the aircraft, but it is envisioned that the majority of DOD aircraft will be modified to accept this system and is considered in the same light as IFF. It does have a deficiency, in that it will tell the aircraft where it is located, but provisions must be made to send this information to the air traffic control center of interest.

The seventh candidate which is not really autonomous system but which is a combination of ON-AXIS, IFF and the NAVSAT which seems to satisfy uniquely all the requirements imposed by DCP 111 and the safety functions which are inherent in any large operation.

- - EVALUATION OF TSPI

We must have a common TSPI on the range. If we are exercising only one aircraft but get three targets because we are tracking with three sensors, we are in trouble. Can you imagine a system with the ACMR and the RMS-2 and a few others all dumping data into a central bus and are all going to give different data? It will be absolute chaos. So what we propose is something completely different, we think, than anything that has been done before. All metric sensors should produce the same trajectory on the same target in real time. This is not done on any range today, except AFETR when ON-AXIS mod is completed. Use an ON-AXIS remote telescope and drive it with an ON-AXIS radar--we will guarantee you it will be centered on the target all the time. To evaluate the TSPI, we are going to take the ON-AXIS telescope and analyze data out of the say, RMS-2, the ACMR, or whatever other instrumentation is available. Adjust the system until it gives us the right answer. That is the way we will calibrate the system. We all simply use the data out of all instruments to supply the driving function, so that we can evaluate it. Too bad we don't have a mobile telescope to go over the ACMR telescope now, we might settle a lot of future problems for COR.

- - REAL TIME VS POST-FLIGHT DATA

Let us talk a little about real time. Everybody defines real time in a different way. We are going to define real time as that data which if not used as generated is forever lost. There is no retrieval, no recovery. If one considers the adjustment to the spacecraft going

into Mars and Jupiter, that is real time. It takes months. This COR system takes a hundredth of a second, it is still real time. Real time in a lot of data processes is running as fast as you can. This is not real time if one makes a mistake and can go back and redo the problem. We see little reason to send anything but results to central control in real time. Really what you want to know is did you shoot that guy down or did he shoot you down? Is that radar jammed or is that radar not jammed? And it doesn't make sense to send where are the switches, and stuff like that in real time. We don't know what you can do with it. The commander of the Red Force or Blue Force, after the fact, may want to look at his video and say, don't do this again. There may be circumstances that cause other data to be sent, in real time, but, as we see it, there is plenty of room in that 240 bit word that we are going to describe. The 240 bit word gives you trajectory ID and some status. We don't see a requirement for a lot of data links coming out of any site. We are going to record detailed digital data on site, all the switchology, many things that relate to how that system operates, but we don't see any sense in sending it out in real time because we do not see any real time use for it. We will reduce this data very, very infrequently, largely in case of catastrophic failures. If something on COR goes wrong and we have to get down to very small detail, then we will take this data and massage it on the big computer in Central Control to find what really did happen. But normally, we record on-site data on a video tape. We are going to show you some of this in a moment. Play it back post flight either at the site or

Central Control if you want to know what happened. We can mix the videos and all the digital data that is relevant, and you can read it as you are looking at it without anymore processing. We put digital data on the TV recorder so you don't have to go back to any computer processing excepting catastrophic failure sense mentioned above. On the video tape, record the incoming TSPI, the internal metric data, weapon control data (switchology), simulation results, J/S, the time of day. You remember all TSPI that is coming in with time on it, that is old time, so we must record the current time of day and some proof that the system is calibrated. We envision these things being recorded at every instrument and that someone at Central Control wants to see them. He can have the video tape brought back, put it on his recorder and he can watch it.

We need a telescope, closed circuit TV, an integrated display, a video recorder that has play-back capability on each one of the systems. We will record mixed target video, which is the analog picture from the telescope or radar video and such digital data as needed. There is no provision in this plan to send this data electrically to Central Control. We do not envision a need to install video circuits to send those TV pictures.

- - CENTRAL DISPLAYS

We must transform the EFG position data to XYZ. The targets will be normally displayed and mixed with a video map. The COR area will be scanned into a permanent video map. The video map may be expanded in any way, superimposed on that will be all the targets with their number and characteristics. It may be transformed into three-D for XZ or YZ

evaluation. An outfit in Lawrence, Kansas makes the 3D rotation systems for $3,000. We can expand the displays to any specific area. We might want to look at the only Caliente or the North Range. We will expand that part and just continue to plot any targets in there. The display can be either on TV or CRT. The TV is about ten times cheaper than the CRT but it cannot draw a straight line across the scope; it has to go in little steps. The CRT can draw a line in any direction. Both are under computer control.

- - AIRCRAFT CONTROL

Let us talk about aircraft control. All sites will get common TSPI. If we have 300 targets, 300 targets will go to every site and every instrument. It does not take much storage (10 each 4096 chips). We will start numbering the targets at 12:00 midnight. We figure 1000 is a big number, but if we need more, we might have to start renumbering at 12:00 noon. That number is not the IFF ID, but is the COR control number. All targets will be designated by that number. We must use geocentric coordinate system. There are lots of targets that won't be aircraft, such as tanks, and people. We will give them a special designator. These targets won't move very fast, but we intend to handle them in that same sense and all current targets will be displayed on Central Control. If the target is on COR, it does not matter where it is, that target will be displayed at Central Control and you can switch to its ID number and find out what the target is doing.

- - MULTIPLE TARGETS

The way we intend to handle multiple targets, is each target will be either ON-AXIS calibrated. We keep repeating the need for geocentric

coordinates use because we do not know of an alternate way. We are going to use 2400-bit data train--2400 being used here only in terms of multiples of 75 bits per second. Although we don't intend to encrypt, we want to make sure that the data are encriptible. The data format from the joint E.W. test, for instance, is 2000 bits per second. Not a thing you can do with it--it is not encryptible. We will end up throwing the stuff away. We will use multiple data streams on the TSPI bus. Every target will be on there. Now the bus can be expanded or contracted as we envision it from a three KC circuit to maybe eight or ten three KC circuits when we have 300 targets. Nonmaneuvering targets will be checked every three seconds and we are going to use an IFF ON-AXIS tracker. Eglin AFB is in the process of IFF designating their ON-AXIS radar to evaluate how long it takes to generate a good ttrajectory. We will show you a tape in which we obtained a bomb trajectory after less than a second of track. If you understood what was said about 160 PRF, it is easy to increase to 320 or 640 PRF if we need to. We can get trajectories in parts of a second, but as of now, we are close to a one second per target update.

- - ON-AXIS TSPI

The IFF/SIF is used for acquisition and for identification. SIF (Selective Identification Feature) means the IFF can identify each aircraft from his own internal signal. The IFF system will turn at 20 rpm. Every three seconds, targets in the field of view of the IFF system will be handed over to the ON-AXIS tracker. The ON-AXIS

tracker will skin track. In the case of IFF jamming, or nonbeacon aircraft, skin tracking will give us the trajectory immediately. If the ON-AXIS trajectory correlates with the IFF return, then no update is required. We have a state vector, the airplane is going straight and level. We will always get the same answer as we move the ON-AXIS data out in time. That will exactly correlate with the IFF data. If it correlates with it, we will just go on to the next target. The computer does this sequentially every three seconds. We will update the trajectory each time the IFF does not correlate. If we update it five times in sequence, we know we have a maneuvering target and it will become a priority target. Only ON-AXIS tracker data will go on the data buss. We should modify that, as any other systems that produce time, position, velocity and acceleration and give the correct answer will go on the data buss.

- - NON-IFF SEARCH RADARS

A number of non-IFF (skin) search radars are available to COR. FAA has some two or three available. In fact, they have pretty complete high-altitude coverage over the whole area. And, in addition, there are a number of search radars associated with COR itself which are normally used as victim radars. The Barlock is an example, but there are a number of other ones--the T-7 and T-8. And when these systems are not being exercised as victims, they can serve a very useful purpose of scanning the skies and seeing those targets which are not IFF-equipped. Now we propose to use this information, not waste it, and feed it into the IFF/ON-AXIS buss in the same that we described the IFF system operation. We will then assign an ON-AXIS track from the data supplied by these search radars, identify those targets that

we don't have a trajectory for, and maintain a vector on the aircraft themselves. This is primarily dedicated to non-COR intruder aircraft and remember we said sometime ago that we really have a scheduled area not a controlled area. So we will expect airplanes to be coming through COR in the time and the manner that won't always be the best from a safety standpoint. We have to know where they are and we will do it in this manner. Now we could go ahead and install ON-AXIS radar systems at the FAA radar. This is being evaluated--it was suggested several times. It always makes it easier to have an acquisition system colocated with the ON-AXIS system itself. This is not absolutely necessary. When this IFF/ON-AXIS system is employed and installed on COR, we see no future need for PPI scopes remoted from the various s arch radars and FAA into Central Control. Now, of course, PPI indicators will still be needed at victim radars. We don't intend to do anything about changing that. But we are simply saying that in the early days in the near-term COR, we certainly are going to remote PPIs from the search radars into Central Control. We see these being removed and no longer needed as soon as mid-term COR comes into being.

- - SEARCH RADAR ECM SCORING

Let us talk about ECM scoring which is another very important consideration. Again, here is something that is not done. What we intend to do, say on search radar, is to gate a small area about each target. This gate won't appear on the scope that is used for controlling. We are envisioning 20 targets, 20 gates which will be moved around in the video as a function of the incoming TSPI. It is based on TSPI predicted target position. We will update it in our

local instrumentation system. We will measure the J/S which is the jamming to signal ratio. The J/S monitor will integrate the total noise in the small gate and compare it to noise just outside the gate. If a target is in the small gate, it will show more energy than the outside gate. If it has the same energy in the gate as out of the gate, then you are looking at noise only. If the J/S is one then the target is jammed. For the first time, we will be able to look at the negative effects of ECM. If the radar has a J/S less than one, the radar operator should see the target. If he has a J/S of one, he is jammed and there is nothing you can do. The operator can't see that target. Consider if we have poor operators, and you penetrate because he is a poor operator. You are not doing yourself any favors; you just think you have ECM tactics that are good. If that J/S equals one, the radar operator still may be able to use the jamming strobes against you. So there is this negative effect that I hope the first time we will be able to measure. We will use J/S to answer Yes he is jammed or no he is not, back to Central Control in real time.

- - ECM SCORING OF MISSILE DEFENSE SYSTEMS

On the subject of ECM scoring, we now come to the various defense systems. Missile defense systems will be discussed and then in this same slide we will discuss the AAA capability. Now the first thing to be done, and this has been done, is to model the missile itself in an on-site computer. This modeling is subject to discussion. A number of agencies disagree on what the model is but this is a software change and what is in the computer is that which we think is best as

of this date. It is subject to change as things or more information becomes available. Now what we are doing is to use TSPI data to recognize the correct target. As we mentioned before many, many times, we find fire control systems engaging the same target over and over again, and then although this might be good from procedural standpoints for training, it certainly is nonvalid in the scoring of countermeasures themselves. In combat, the target would have been engaged and either missed or shot down. So we have to take steps in this environment to remove the airplane that is killed. And we will do this by using TSPI to project out into space where the target will be and to use the missile simulation to tell where the missile itself will be and this will, of course, include fusing and other important considerations like this. Again, the subject of measuring J/S comes up. It is important to know that the jamming you are doing is in effect doing everything against that system that the jamming can do, and if the J/S is one, your jamming is in fact "jamming the thing." That does not mean again that he cannot use strobing against you. We should like very much to point out that when you use countermeasures, you immediately solve the enemy's GCI problem and tell him here I am boys--come and get me. And unfortunately in the last few years, that is exactly what he has done. So, again, we come to the subject of looking at the negative results. I think it is extremely important that we do this. It is inherent in J/S measurements and will be in both the antiaircraft and the missile defense scoring systems. We will send the scoring

- - WEAPON SCORING

Now enough about scoring ECM, let us get on with the discussion of scoring weapon systems themselves. In general, we propose using an ON-AXIS radar because it will produce very accurate data in real time. By this we mean it will give us the trajectory of the weapon, for example, a bomb. We will show you some video pictures of what we are talking about. The ON-AXIS systems will have boresight photo data as well as trajectory output, so that if you really want to get down to very, very close ballistic numbers, say on a bomb drop, it is easy to do by going back and superimposing the minor deviations one will see in the boresight telescope on to the real time data produced by the data stream. The scores from say these weapon systems can be sent into Central Control in real time if they are needed. This may be important in a defense suppression mode, but again, it can be treated in almost identical manner to the antiaircraft and other systems. One of the very strong features that we are seeing in the ON-AXIS radar is that we can either simulate or do the actual weapon launch with the same instrument. No instrumentation at all needed on the aircraft. And we can begin to get numbers of the dispersion between the two. It has been demonstrated before that accuracies of ten feet are not hard to get. And we think that will more than satisfy anything we are talking about on COR. If the need is to go beyond that, and we don't see it today, it is simply a matter of modifying the individual ON-AXIS instruments with better encoders and resolution in the digital range machine. There is one relatively minor problem in order to do the weapon scoring, whether

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it is air-to-air missile launches or bomb drops--that sort of thing. We generally need some sort of alert signal from the aircraft that the event is taking place. In the past we have done this by using a release tone from the aircraft. Now in most cases, this is a manual process which may tend to introduce error in the system. Maybe in the future we will make this automatic, but, for the time being, we will stick to the bomb release tone that we have used successfully at Eglin and Patrick AFB. We think in that way we will be more than capable of scoring these weapons both in a simulated and actual sense beyond anything that we can in fact do today on a routine basis.

- - AIR-TO-AIR SCORING

Now there is another rather large area which we spoke of and that is the air-to-air scoring problem. Although it could be done with the ON-AXIS systems and may at one time be done that way, what we really can see happening in the mid-term COR is the use of an ACMR or something like it will be on COR. We have to integrate it into the system. So we use the ACMR as an air-to-air scoring device recognizing that it is only capable of doing the job in a simulated sense. There is no capability in that system to do live scoring. We will have to integrate it into COR TSPI buss; however, the ACMR data has been looked at very carefully and it will not fit as it is now produced. It is internally consistent, it is more than adequate for the training mission, but when we talk about using it for TSPI, that is a totally different ball game. So we will have to do some rather careful analysis and make sure that we get the same answers out of the COR TSPI and the ACMR data. There

are serious deficiencies as I mentioned in things like the ACMR and one of them is its relatively restricted range, when we look at high-speed aircraft. The total time, say on a relatively slow aircraft, 500K or so, is like four minutes across a whole ACMR range. And, high-speed aircraft will be through the system before we can even set it up. So we will use the ON-AXIS systems and do the pre-range setup using TSPI so that we can control the action in the ACMR arena itself. Now again the ACMR and other systems use pods for attitude data. The pods are used for a lot of other things besides attitude but the point we want to make here, is that we consider the need for hanging a pod on an aircraft really is an interim solution. The use of a pod should be avoided simply because there are many types of aircraft that can't carry a pod and we can do the job without the pod. Now a very interesting thing relating to pod is developing. That is the use of pods without a ground range at all. We had a proposal in which it looked extremely good to do the air-to-air evaluation away from anything called a range itself; just hang pods on two aircraft or four aircraft and send them out--let them do their unrestricted air-to-air combat and either do real time scoring or postflight scoring without any of the constraints whatsoever of a ground range. And we think that is the way the system should go. Now getting on a little different subject, but related to air-to-air scoring, is the use of the IFF system to send data to the ground when we need it. We have already discussed the future use of NAVSAT and the need of sending the NAVSAT data down to the ground from the aircraft. We believe a continuing project should be initiated

immediately with the thought of sending the necessary down-link data through IFF for any of the systems that we are going to test in the future. Tremendous savings will accrue because we will not have to go out and build special systems everytime we want to test an aircraft system. All DOD aircraft will all have IFF and they probably will all have NAVSAT equipment on board. This capability is beyond COR because the FAA and other systems will need to know where the aircraft is and it may be that the cheapest, best and quickest way of solving a problem is to modify the MARK 12 IFF systems to send this kind of data in the down-link. With air-to-air scoring, we again intend to display results in Central Control. However, in this case, for postflight analysts, we see a playback capability similar to that existing in the ACMR today so that the instructor can, in fact, analyze what the combatants did wrong; why one was victorious and other one was not. And that is built into the system so we don't see any need to change it. Now again back to the NAVSAT discussion, one of the serious weaknesses of the ACMR and other multilateration systems is that a planor installation capability have very poor Z definition. We may want, in the future, to marry NAVSAT information into these other systems to increase their potential in the Z or up/down domain. This not only includes ACMR but RMS-2 and other systems. This is something for the future; we don't think that it is something we have to worry about right away. But there seems to be a potential in marrying NAVSAT to other systems being considered.

- - TSPI REVIEW

Now let us go back and try to review the TSPI situation itself. OT&E, as such, depends on metric data among other things; probably on

as much on metric data as anything else. COR needs high metric accuracy in certain areas. Maybe not in all of them. It may be that because we need high accuracy in several areas that it would be easier, and standard, and cheaper, to maintain high accuracy all over. In general, for ECM scoring, weapon system scoring, and traffic control of large numbers of aircraft maybe, not formation flying, but certainly cross-gaggle flying for ECM separation, all require high accuracy. One needs to know where every aircraft is and needs to be able to remove them, if required, so the scenario is maintained. Now there are a number of candidate systems being evaluated, as we mentioned--we reviewed them. And one of the more promising ones is the use of ON-AXIS radars.

- - NIKE HERCULES

There are available several systems that could be modified to ON-AXIS. One of the very promising ones is the NIKE HERCULES. These are surplus now. But the point we would like to make, there isn't enough money in the foreseeable future to do COR anywhere near the way we should do it without using some of this excellent surplus equipment. It may be, the only way we are going to get from here to there. Hopefully, we are starting early enough in the development of COR that we can do it right this time so that it won't grow like Topsy and never really solve the problem. So TESPO is looking very carefully at these NIKE HERCULES systems, which have several really attractive features aside from their excellent radars. One important feature is that the systems themselves are mobile. When we build systems we tend to really compromise

their capability when we make them mobile, and we are talking particularly about radars. These are not in that category; these are very well-designed mobile systems. Strictly from a mobility standpoint this NIKE HERCULES pedestals are tremendous. They are old--there is not a question about it, they are all analog systems and will have to be converted. We are going to talk about that in a moment. They also have their own mobile power equipment. So what we see down the track is COR having these systems stationed around; with this capability already inherent, we don't have to develop it, but it and pay for it. It also gives us a potential to go anywhere in the world to do this same kind of job, if we can do this system right.

- - STATUS OF NIKE HERCULES

Now the status of NIKE HERCULES systems in the United States to the best of my information is that the total Continental system is being decommissioned. We know that to be a fact. We really can't tell how much of it is being surplused. We know that there are some 25 systems that are available in the very near future. Whether all of them will be surplused or some of them will be sent to overseas customers, we don't know that this has been decided. But we think we should consider requesting the complete NIKE systems minus the missiles. We don't believe we can use those and they are in fact needed for some foreign customers. There are five radars in the NIKE systems and we certainly won't use them all. We are not ready to go in and chop them up at this state of the game. In fact, there is use for almost all of the pieces

so we are suggesting that we ask the Army to transfer some 24 of these systems to TESPO. We will place them in either local or mass storage so that they will not have disappeared by the time we need them. Now already, a number of agencies have started modifying the NIKE HERCULES. It's becoming very chaotic. We think if we do it in an organized straight-forward manner, we will solve a lot of people's problems in addition to our COR problem. And we will do it at a pretty low cost compared to what you would pay to go out and buy a system like this. You know, we are finding that since we started this that there are many people around the country with a few hundred thousand dollars to go do a certain test job and they consider acquiring a HERCULES and modifying it. In effect, this will result in a poor job of modifying these systems out. If say, Wright-Patterson needs to do a test we should move one up there and use it; if there is a need to do a test at some other location, maybe around the world, that capability should be inherent and exist so that we can just move out and go do the test. And we are not talking particularly about OT&E, but, in fact, in several areas of DT&E. The day and the need for formal ranges to do this kind of testing, we think, is rapidly disappearing.

- - ACTION NIKE HERCULES

Now the NIKE HERCULES system, as we mentioned, are all analog. They are excellent--they are really good from that standpoint, but we don't think we would want to try to maintain a system that is all analog if only because it is horribly expensive and the logistics problems are

terrible. The Army will in fact maintain supply on the NIKE HERCULES throughout 1985, primarily because of the overseas commitments. There is a much better way and much cheaper way and that is to digitize the system. We are proposing to modify it ON-AXIS in the exact same sense that we have done to the FPS-16s and the NIKE X and other ones. And in doing this, we pretty much used federally stock listed parts. The system becomes a digital radar if you--digital ON-AXIS radar. Now there is a point here to be made that we have not talked about before. When one buys a radar to put on a range, the cost is only starting when you get the radar. You have to put a clock in it or, to make time available, you've got to put in a data system. There are so many things that you have to add to the system to make it part of a range, that you spend more money to marry the radar into your system than you did purchasing the radar. In this case, we hope to circumvent this completely. When we get through modifying these systems to ON-AXIS, they should be able to be plugged into any system without additional cost. Now what we are proposing to do here is to make this part of our COR Development Plan which is now being prepared. We do not think there is much risk in the approach if we do it in an organized manner, but we have not worked out the details on how we are going to do it, as of this date.

- - WRAP UP

In order to wrap up the whole system and the whole briefing, we should like to say that we have not done the systems analysis for mid-term COR; we have done a fairly thorough technical analysis on one solution--it may be the only one, but we are not going to evaluate that now. We are

still looking for other possible technical solutions. Again, we would like to point out, COR will probably be the first real time range. All of the other ranges have built very large post-flight analysis facilities. They had to do it that way because of the way the system grew. But, the COR need is for real time. We see a cheaper and easier way of doing the job. So we have got to do the cost estimates and certainly the trade-off analysis in the best way to do the job and hopefully we will have that done in say another 12 to 18 months from today.